TECHNICAL REPORT – STUDY / SERVICES

CDRL A002

FINAL REPORT FOR THE

ADAPTIVE REMOTE SENSOR COMMUNICATIONS SBIR PHASE II PROGRAM

SPONSOR: Naval Sea Systems Command
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SECTION I

A. INTRODUCTION

This is the Final Report submitted in support of the Adaptive Remote Sensor Communications SBIR Phase II Program, Contract number N00024-08-C-4148.

This document addresses CDRL Item A002, Final Report. The report will be updated after review and completion of remaining Option, when exercised, and resubmitted at the conclusion of the final Option program as the revised Final Report.

In this document, "MVCS" refers to the existing Multiple Vehicle Communications System currently in development. "EMVCS" refers to the enhanced, updated MVCS (integrate with this SBIR activity, N06-053 Triton, Mission Planning Tool).

A1. Background Information

The future naval tactical combat system will include a network of multiple acoustic and non-acoustic sensor modules deployed on airborne, surface, and sub-surface unmanned vehicles. Command and Control (C^2) information will be sent to the sensor platforms (off-board vehicles), and sensor data will be communicated from off-board vehicles back to the LCS through a variety of communications paths that could include Line of Sight (LOS), satellite, other Beyond Line of Sight (BLOS) and acoustic data paths.

A prototypical example is the Littoral Combat Ship (LCS). This ship is envisioned to be smaller, less expensive to build, with the flexibility for supporting a variety of focused missions through the use of modular Mission Packages, and standard open interfaces. A Mission Package may consist of a combination of modules, manned and unmanned off-board vehicles, deployable sensors, and mission manning detachments

The LCS will have a core C^4 system that will support mission and ship systems for tactical and non-tactical operations, including the capability to fully integrate into FORCEnet. The C^4 system will conform to the Navy's Open Architecture program guidelines and standards, will be interoperable with embarked Mission Packages and joint forces, and integrate all sensors, communication systems, and weapon systems into a single C^2 system.

The mission platforms (off-board vehicles) have benefited from developments in naval communications technologies and data networking protocols that have improved the bandwidth and range of remote sensor connections. Currently, they utilize a potpourri of communications systems. The communications links include both acoustic and Radio Frequency (RF) links, and range from HF to SHF. The links provide a variety of communications services and throughputs, ranging from hundreds of bits per second to megabits per second. Some are Internet Protocol (IP) based, others are not. Some use "nomenclatured" systems, such as the AN/VRC-99 or RT-1944/U, while others use Commercial-off- the-Shelf (COTS) point-to-point links. While extended BLOS capability is desirable for all platforms, some of them currently provide only LOS capability. Some utilize alternate communications for LOS, BLOS and/or deployment-recovery, others may not. Link performance can vary significantly, from wide bandwidth "pipes", to limited throughput because of range, interference or jamming. Data pipes can also be “broken”, with throughput falling to zero, due to wave blockage.

The demands placed on these and future communications links, which may include a combination of high capacity LOS, medium capacity—medium range BLOS, and low capacity long-range BLOS, continue to increase due to (1) higher bandwidth sensors, (2) increasing complexity of remote sensor packages with active sonar, passive sonar, video/infra-red, radar, and electronic surveillance components, and (3) increasing number and types of remote vehicles. Currently, only communications systems “of record” are being utilized. The future, however, could include additional solutions, such as very high bandwidth, wideband networked waveforms using UAV relays, or more esoteric waveforms allowing BLOS operation, to support the existing vehicles, via spiral insertion, or in yet-to-be-defined vehicles.

With smaller ships like the LCS evolving to dominate the littoral battlespace there will be limited manpower available to manage these diverse multi-vehicle sensor systems. Operators will not have sufficient time to continuously monitor and adjust the described, and future, communications assets in response to rapidly changing battle conditions. Further, an operator skilled in the art of, for example, ASW may not necessarily understand the detailed subtleties of managing complex communications links, nor will he likely have the ability to adjust the links in the time available. This is the essence of the problem, as exemplified in Figure 1.1. The desired SBIR innovation is to develop technology to monitor these multiple communication links and automatically detect nominal performance, failures, degrading performance, or improving performance. In response to a change in monitored performance, the system will dynamically reconfigure remote vehicle links or remote sensor operating modes, in order to optimize link performance within new constraints suggested by the link state. Operational benefits of this technology will include faster adaptation to changing link conditions, increased operational availability, reduced operator workload, improved remote sensor performance, more efficient bandwidth (spectrum) utilization and a common “fail-safe” command link to ensure vehicle safety.

Figure 1 Adaptive Remote Sensor Communications Problem Dimensions

A2. SBIR Program Summary

The overall SBIR objective is to develop a Mission Planning Tool that will effectively manage a diverse set of communications links, minimizing operator interaction while maximizing the links' communications efficiency.

The Phase I objective was to define and document a concept for automated monitoring and reconfiguration of remote sensor communications that supports the overall LCS mission objective. An optional early demonstration is proposed to mitigate Phase I identified risks, and to act as a bridge to more extensive development, testing and demonstration in Phase II.

In support of this objective:

- Problem definition and requirements analysis activities assisted in establishing a set of strawman requirements for the system, called the Enhanced Multi-Vehicle Communications System (EMVCS).
- A conceptual design for the EMVCS was generated.
- An EMVCS KBES is planned to be demonstrated in a lab environment, with the intent to mitigate risks and serve as a bridge to additional Phase II research activities. (Optional task).

This Phase II objective is to develop and produce a prototype EMVCS. In support of this objective:

- The EMVCS specification, developed during Phase 1, was updated.
- The system design will be finalized, best effort.
- A prototype EMVCS was assembled.
- System performance characteristics will be evaluated via demonstration and subsequent data reduction, working in concert with the sponsor, and utilizing a subset of the unmanned platforms and/or surrogates. (Option not yet exercised)

A plan for the transition of the developed adaptive communications technology into the LCS tactical mission packages will be prepared. (Option not yet exercised)

The Phase 3 objective is to produce qualified EMVCS systems. In support of this objective

- An updated specification, including all operational requirements (environmental, logistics, documentation, etc) for the production units, will be prepared (based on previous versions).
- A complete design package and system cost estimates for future acquisition will be prepared.

A pre-production qualification unit will be built.

B. RESULTS SUMMARY

The Triton Mission Planning Tool (MPT) was designed to partially automate the optimization of communication system parameters for naval mission scenarios. This Summary provides a brief description of the SW functions and steps required to install and use the MPT.

C. MPT INSTALLATION

The Triton2 MPT integrates an assortment of applications into a single workflow. The following procedure can be used to install these applications, prior to the first use of the MPT.

Install the Java Runtime Environment.

Navigate a web-browser to http://www.java.com to download and install the latest Java Virtual Machine (JVM).

Obtain/Install AREPS.

Downloading AREPS requires that the user first create an account with the Space and Naval Warfare Systems Center (SPAWAR) before downloading the AREPS software. Appendix B provides instructions on how to create the account and download AREPS.

Once downloaded, AREPS installation is relatively straightforward. Extract the contents of the zip file and double-click the "**Setup.exe**" file.

If prompted for a registration number, feel free to select "next" as the extended AREPS features are not needed by the MPT.

Install Google Earth (optional).

Navigate a web browser to http://earth.google.com to download Google Earth.

Once downloaded, Google Earth installation is relatively straightforward. Double-click the "GoogleEarthSetup.exe" file to install.

Install the TRITON_MPT tool.

Unzip the "**TRITON_MPT.zip**" to any desired directory.
(e.g. C:\TRITON_MPT, C:\Program Files\TRITON_MPT, etc).

Inside the extracted folder there should be a file called "ExternalDependencies.xml". Using a text editor, edit this file to reflect the locations of the software installed in the previous steps. Table 1 provides a brief description associated with each of the fields inside this file. It is possible that no changes will be needed if the default install directories were selected during the installation of AREPS and/or Google Earth.

At this time, it may be helpful to create a Windows shortcut to the executable file. This can be accomplished by right-clicking on the "**TRITON_MPT.bat**" file inside the directory extracted in the steps above, selecting the "Create Shortcut" option. This shortcut can then be copied to the Computer's Desktop or Start Menu.

The user may also find it helpful to install and use an XML editor to edit the "Mission Plans" and associated configuration files. There are a variety of XML editors available on the open market. Table 2 provides two suggested applications.

Table 1 External Dependency Fields Inside "ExternalDependencies.xml"

Field	Description
PATH_TO_AREPS_EXECUTABLE	Path to the installed AREPS executable.
PATH_TO_ENVAREPS_EXECUTABLE	Path to the installed envAREPS executable (bundled with the AREPS install).
PATH_TO_GOOGLE_EARTH_EXECUTABLE	Optional: Path to the installed Google Earth executable.
PATH_TO_AREPS_PROJ_FILES	The folder under the AREPS directory structure where AREPS expects its Project files.
PATH_TO_ENVAREPS_WEATHER_FILES	The folder under the AREPS directory structure where envAREPS expects its Weather data files.
PATH_TO_TEMP_DIRECTORY	A folder where the MPT can assemble temporary files during the course of execution.
PATH_TO_MISSION_FILES	Default path to the directory where MPT mission XML files are stored.

Table 2 Recommended XML Editors

Software Product	Description
Altova XML Spy	Excellent XML editor that provides XML syntax highlighting and editing capabilities. Includes a variety of useful features including graphical representation of the XML structure as well as more "user friendly" XML editing capabilities. http://www.altova.com/xmlspy.html
Notepad++	Free text editor that provides XML syntax highlighting and editing capabilities. http://notepad-plus.sourceforge.net/uk/site.htm

D. Using the Triton MPT Application

This section provides a step-by-step overview of a typical MPT use case.

The MPT accepts XML Mission Plans defined in accordance with the established XML schema. Example Mission Plans and schema have been included in the formal delivery materials. This section assumes the desired XML Mission Plans have been edited external to the MPT.

To get started, double-click the "**TRITON_MPT.bat**" batch-file that was extracted from the "**TRITON_MPT.zip**" file during the installation procedure.

MPT Layout Overview

Before describing the steps involved in using the MPT, it may be appropriate to first take a moment and discuss the layout of the MPT's graphical user interface (GUI). The MPT was designed to highlight its two major capabilities: loading unique, user-defined mission plans and displaying information related to whether the mission's communications links can be closed. As such, the interface is divided into two tabbed-sections:

Mission Overview – Presents key features of the currently loaded mission plan.

Mission Planning Results – Displays formal results describing whether the mission's communications links can be closed.

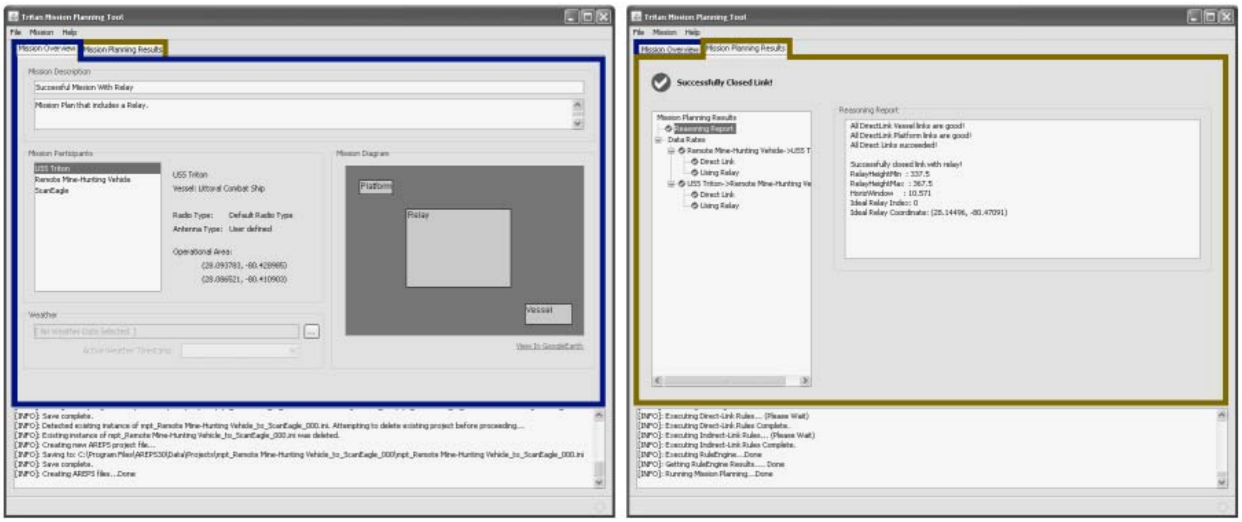

Figure 2 Mission Overview display (left) and Mission Planning Results display (right)

During a typical use-case, the MPT automatically transitions between the two displays, providing an appropriate view for the performed actions.
A logging window is displayed at the bottom of the screen, independent of the two tabs mentioned above. This window displays logging information from MPT as it performs actions. These statements can serve as both informational and diagnostic tools.

Loading a Mission Plan

The first step in using the MPT is to load a Mission Plan. This can be accomplished by selecting the *Load Mission Plan XML* option from the *File* menu*.* ("*File->Load Mission Plan XML*")

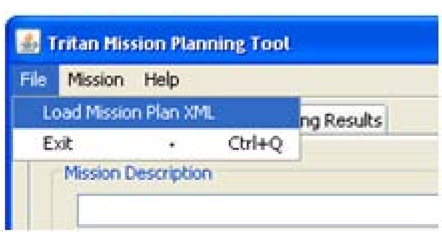

Figure 3 Loading a Mission Plan

The Mission Plan XML files were designed to be constructed outside of the MPT tool. Example mission plans have been provided in the Triton2 software delivery materials and Appendix A provides a description behind their XML organization, in the event that the user would like to construct new mission scenarios.

Once successfully loaded, a description of the selected mission plan is displayed in the MPT's *Mission Overview* tab.

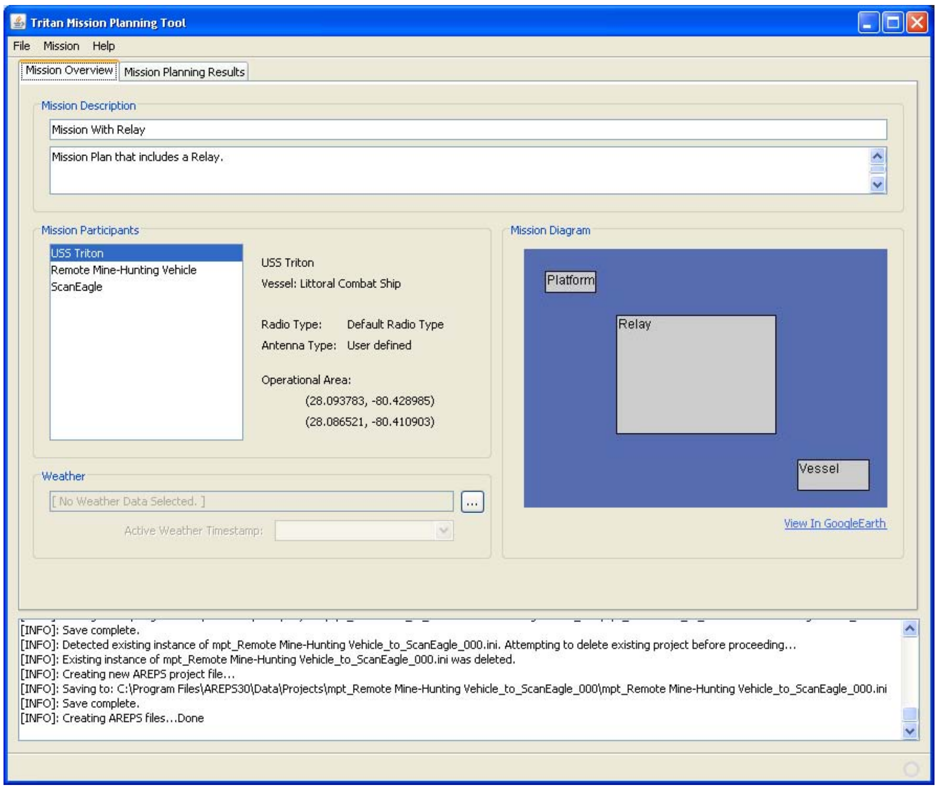

Figure 4 Loaded Mission Plan shown in the Mission Overview Tab

The key portions of the *Mission Overview* tab are "Mission Description", "Mission Participants", Mission Diagram" and "Weather". The following sections provide brief descriptions of these areas.

Mission Description

This simply shows the name of the Mission Plan and a brief description of it.

Mission Participants

The Mission Plan defines a vessel (such as an LCS), a relay (Such as a ScanEagle) and a remote platform (Such as a Mine Hunting platform). This section provides a list of these mission participants, allowing the user to click on each participant to display more information about the participant (Participant name, participant type, radio type , antenna type, and operational area).

Mission Diagram

This display is a simplified diagram of the relative positions of the mission areas of the three elements listed in the Mission Participants section. There are no latitude or longitude labels but the areas are to scale. For a more detailed view of the operational areas, the user can also click on the "View in Google Earth" label which will launch and load the operational area information inside Google Earth.

Weather

This area provides a text description of the loaded weather file. See Section 3.3 for more information.

Loading Weather Information (Optional)

As an optional capability, use of weather COAMPS data from the Fleet Numerical Meteorology and Oceanography Center (FNMOC) can be included in the MPT's calculations.

This weather data must be manually retrieved from the FNMOC. The retrieved file will be in a zipped format and will need to be extracted, revealing an enclosed file with a PRF extension.

Load the COAMPS data into the MPT via the *Load Weather From File* menu option from the *Mission* menu. ("*Mission->Weather->Load Weather From File"*).

Figure 5 Loading Weather Information

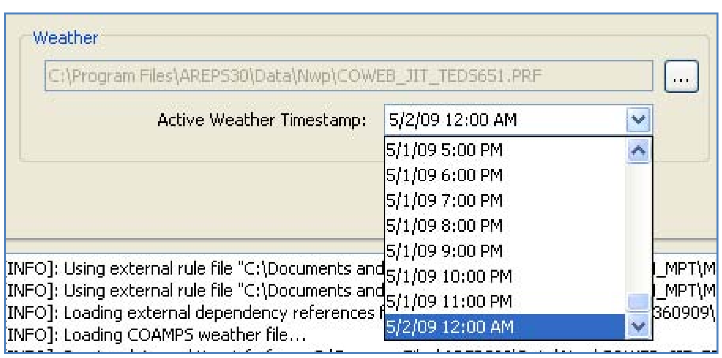

Figure 6 Selecting the Desired Weather Timestamp

Running Mission Planning

Mission planning attempts to analyze all of the available information to determine if the mission's communication links can be closed while achieving the users' desired data rate (user data rate is specified in the Mission Plan). If a relay is involved, the MPT also attempts to identify the optimal relay location within its specified Operational Area.

Start mission planning by selecting the *Run Mission Planning* item from the *Mission* menu. ("*Mission->Run Mission Planning"*)

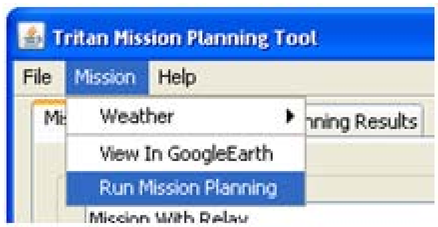

Figure 7 Running Mission Planning

Mission Planning may take a short while to complete as it performs an exhaustive analysis of every conceivable communication link in the mission area. When its calculations are complete, the MPT will display the *Mission Planning Results* tab, providing a report of its conclusions.

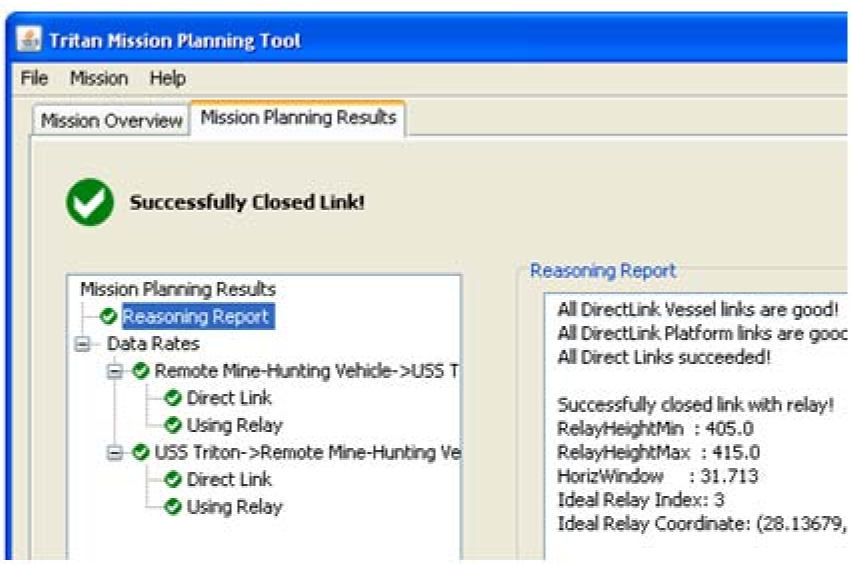

Figure 8 Mission Planning Results

Understanding the Mission Planning Results

At the end of Mission Planning, the MPT provides a final report describing whether the MPT was able to identify a successful communication link.

The *Mission Planning Results* tab consists of two major sections illustrated in the figure below. The first is the *Result Description Tree* which provides a mechanism to navigate through the results. Whenever a field is selected inside the tree, the *Detailed Description Panel* will change to provide detailed information about the specific field.

When the *Reasoning Report* is selected in the *Result Description Tree*, the MPT updates the *Detailed Description Panel* to provide an explanation of how it was able to close the link.

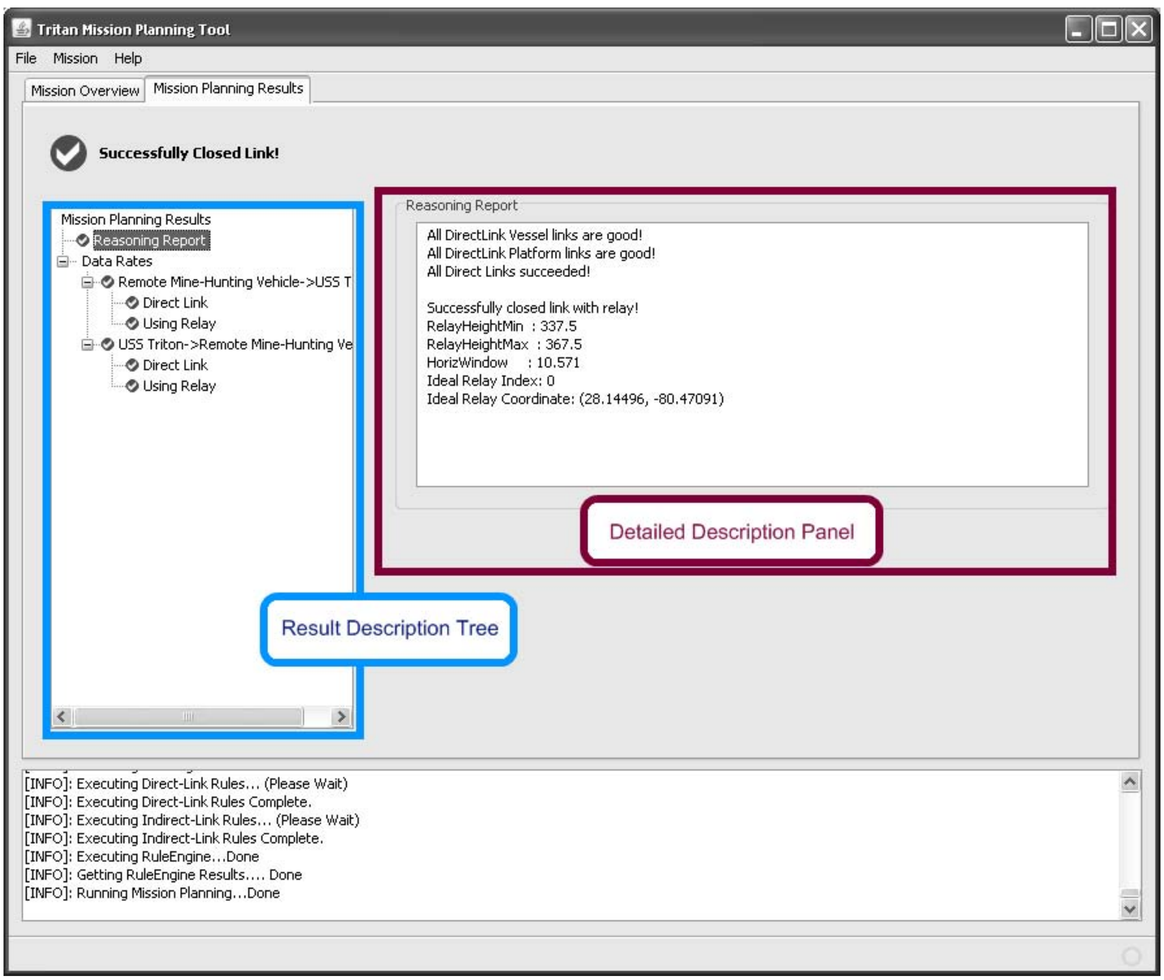

Figure 9 Mission Planning Results Breakdown

E. Mission Plan XML Organization

This section provides a brief summary of the XML file organization used to describe a Mission Planning scenario.

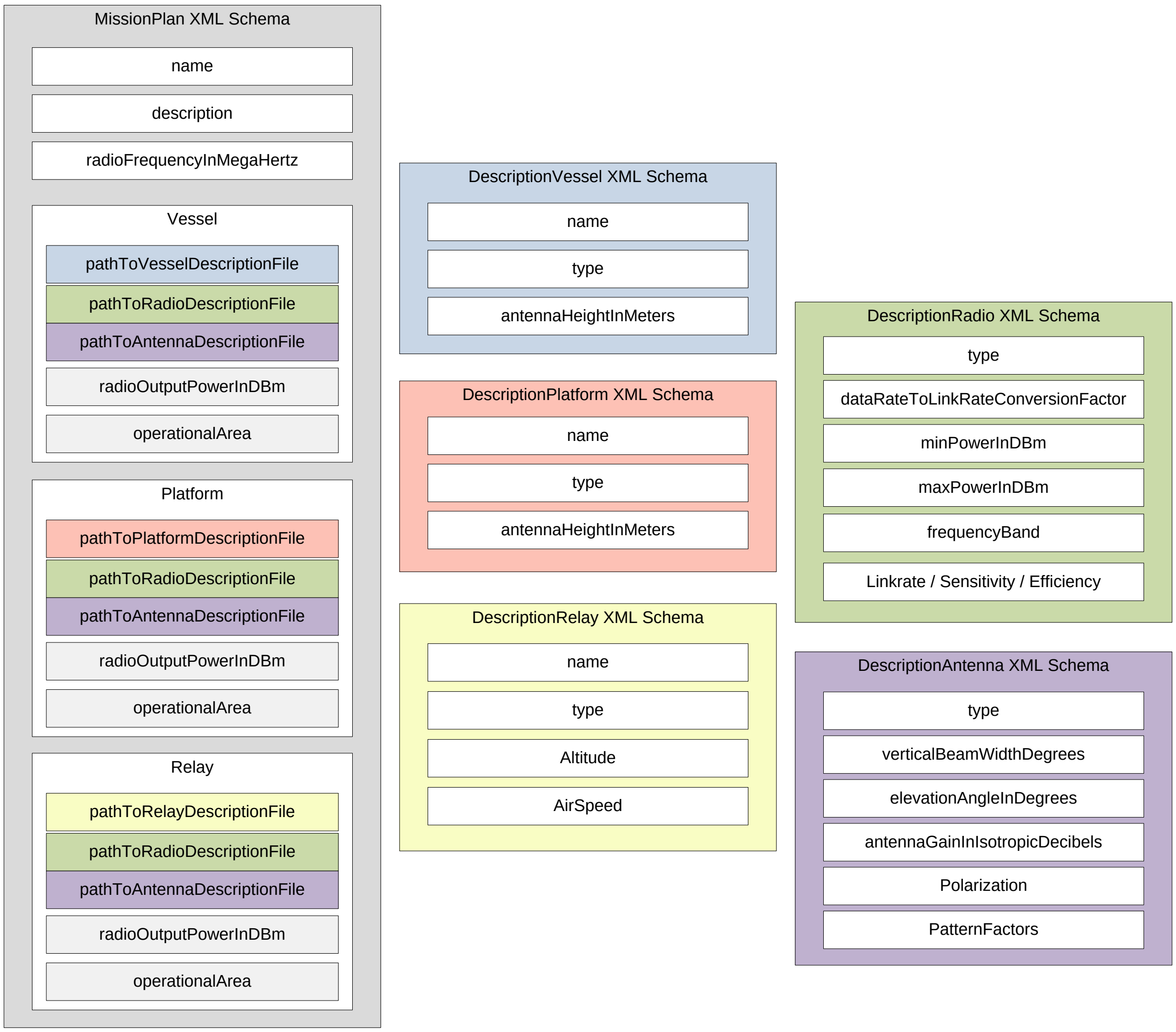

Figure 10 Mission Plan XML Organization

The Mission Plan's XML files are organized with modularity as a key design consideration. As such, the Mission Plan has been broken into six distinct XML schemas that are referenced from a central Mission Plan XML file. A typical mission plan will consist of ten unique XML files linked from a central Mission Plan XML file.

The following sections provide brief descriptions of the six XML file types shown in the diagram above.

Mission Plan XML

The central XML file contains the core details associated with the overall Mission Plan, namely the mission participants (a vessel, a platform, and an optional relay), their respective geographic locations, and hardware configurations (radio, antenna, antenna-height / altitude).

The mission participants described in the Mission Plan XML file reference external XML files that provide additional information about the mission participants.

Vessel Description XML

The Vessel Description XML file contains detailed information describing the mission's vessel (e.g. littoral combat ship). Key fields within this XML object are the vessel name, the vessel type, and antenna height.

Platform Description XML

The Platform Description XML file contains detailed information describing the mission's sensor platform (e.g. remote mine hunting vehicle). Key fields within this XML object are the platform name, the platform type, and antenna height.

Relay Description XML

The Relay Description XML file contains detailed information describing the mission's relay object. For the purposes of this program, it is assumed the relay is an aerial vehicle with a minimum/maximum altitude. Key fields within this XML object are the relay name, relay type and minimum/maximum altitude.

Radio Description XML

The Radio Description XML file contains detailed information describing each of the radios associated with every mission participant. The files contain a number of key fields used to determine whether the communications link can close including sensitivity and link efficiency measurements.

Antenna Description XML

The Antenna Description XML file contains detailed information describing the antennas associated with every mission participant. The files contain key features including pattern factor measurements and antenna gain information.

F. Obtaining AREPS [Advanced Refractive Effects Prediction System]

AREPS is a software application developed by the Space and Naval Warfare Systems Center that allows for the identification of RF path-loss in a communications link. AREPS is a licensed application. This section provides a brief summary of how to obtain a license and download the AREPS installer.

- The end-user needs to navigate a web browser to: http://areps.spawar.navy.mil/.
- On the left hand side of the page, click the link labeled “Software Programs”.
- Under “Advanced Refractive Effects Prediction System” (AREPS), there is a link to “Request the AREPS program.”
- The resultant page displays a form that needs to be filled out in order to obtain an account.
- A SPAWAR representative should acknowledge the request within a day or two and will provide a link to download the AREPS installer (a 25MB zip file).

SECTION II

A. Phase II RESULTS

RSS Corp. accomplished the following major tasks on Phase II Basic and Option 1. NOTE: Option 2 has not been exercised and according to the contract will not be exercised until this Final Report is submitted.

- Prepared a program plan/schedule for Phase II work efforts
- Performed PDR and CDR
- Prepared and coordinated Technical Interchange meetings with subcontractors Northrop-Grumman and Harris Corp.
- Assembled a surrogate MVCS system for LCS and one Mission Module
- Developed and tested on Computers the Mission Planning Module SW
- Delivered first software version of the Mission Planning Tool to the Government
- Defined the SNMP [Simple Network Protocol] interface for the RT-1944/U radios for development of the JAVA to SNMP SW module development.

Future Unfinished/Unfunded Tasks for this SBIR program

NOTE: Option 2 to perform these Tasks has not been exercised and according to the contract will not be exercised until this Final Report is submitted.

- US Navy NUWC Panama City MVCS person[s] to visit RSS Corp. facility and install latest MVCS operational SW into the MVCS rack assembled at RSS.
- Completion of the JAVA to SNMP translator SW module for the RT-1944/U radio.
- De-bug Mission Planning Module SW to correct any operational deficiencies
- Run a pre transition test of the Mission Planning Tool SW on the MVCS rack
- Update this Final Report
- Perform technical management of a Mission Module Planning Tool Transition Event planned and run by Navy personnel

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